UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

Multi-FPGA HPC Applications - MulFPGA -

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High-Performance Computing Group
Paderborn Center for Parallel Computing

Paderborn Center for Parallel Computing

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High-Performance Computing Group

High-Performance Computing Group

- Research in HPC methods and architectures
- Focus on accelerator technologies / heterogeneous computing
- Unique in its activity in the field of FPGA accelerated HPC
- Close connection to the Paderborn Center for Parallel Computing (PC2)

Paderborn Center for Parallel Computing

HPC Applications: Modeling and Simulation

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climate prediction

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mechanical structure simulation

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protein folding

HPC Applications: Optimization

airflow optimization

fuel combustion optimization

evolved antenna
(designed with
evolutionary algorithm)

HPC Applications: Analytics

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DNA sequence analysis (bio informatics)

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social networks

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astrophysics (sun spot activity)

Supercomputer Noctua 2

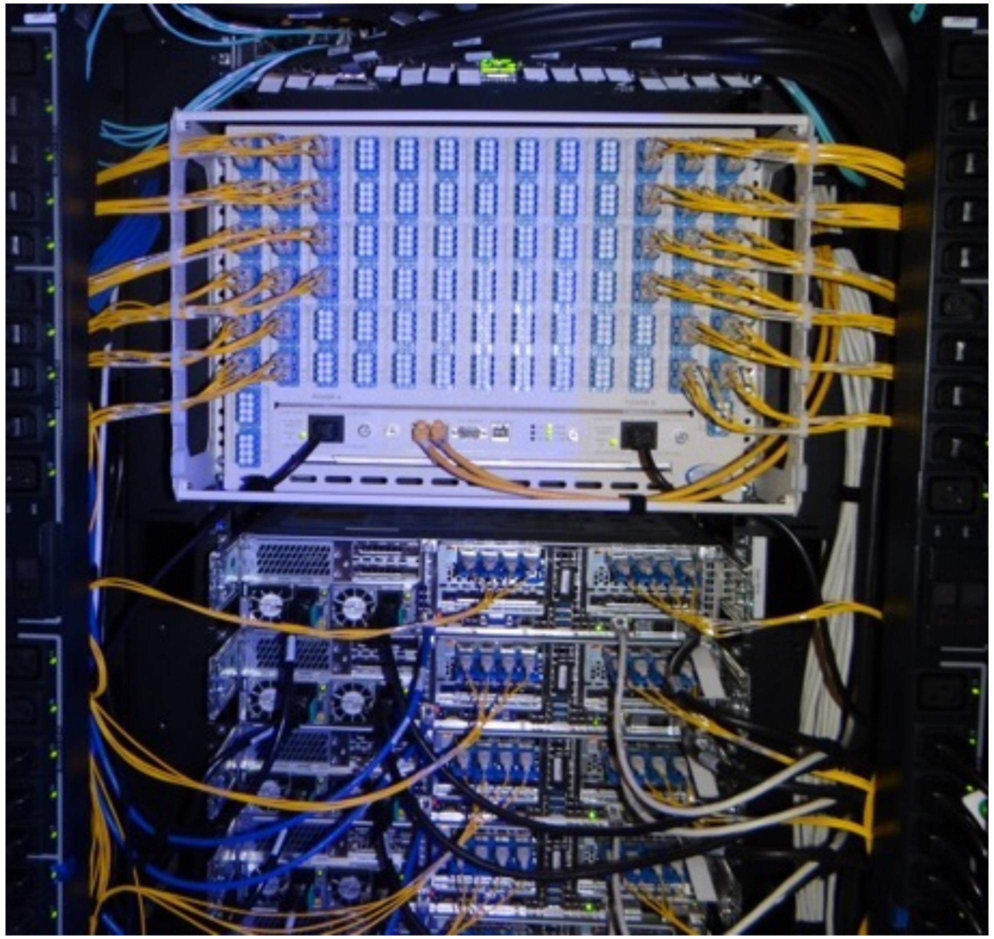
- HPC applications need immense compute power
- Only achievable with high degree of parallelism
- Nowadays: Use of accelerators (GPUs / FPGAs) to increase efficiency
- Noctua 2 @ PC2
  - 1,124 servers
  - 143,872 CPU cores
  - 128 NVIDIA A100 GPUs
  - 100 Gb/s InfiniBand network
  - **48 Xilinx Alveo U280 FPGA accelerators**
  - **32 BittWare 520N with Intel Stratix 10**

Supercomputer Noctua 2

- Worldwide unique setup:
  - Top of the line FPGAs of both big vendors
  - 80 FPGAs within a single cluster
  - Direct optical network between FPGAs
  - Optical circuit switching for ultra low latency
  - Possibility for custom network topologies and protocols

- Chance to combine FPGA acceleration with parallelism

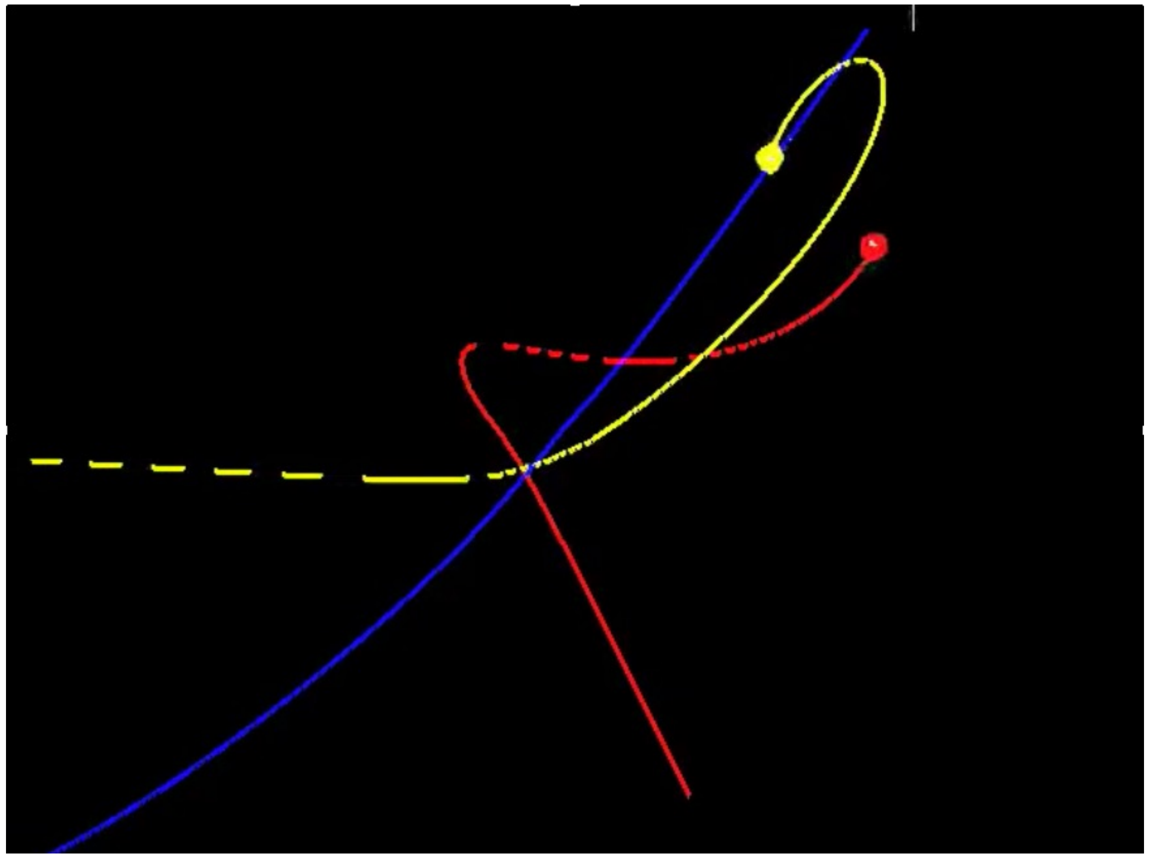
  → Multi-FPGA implementations



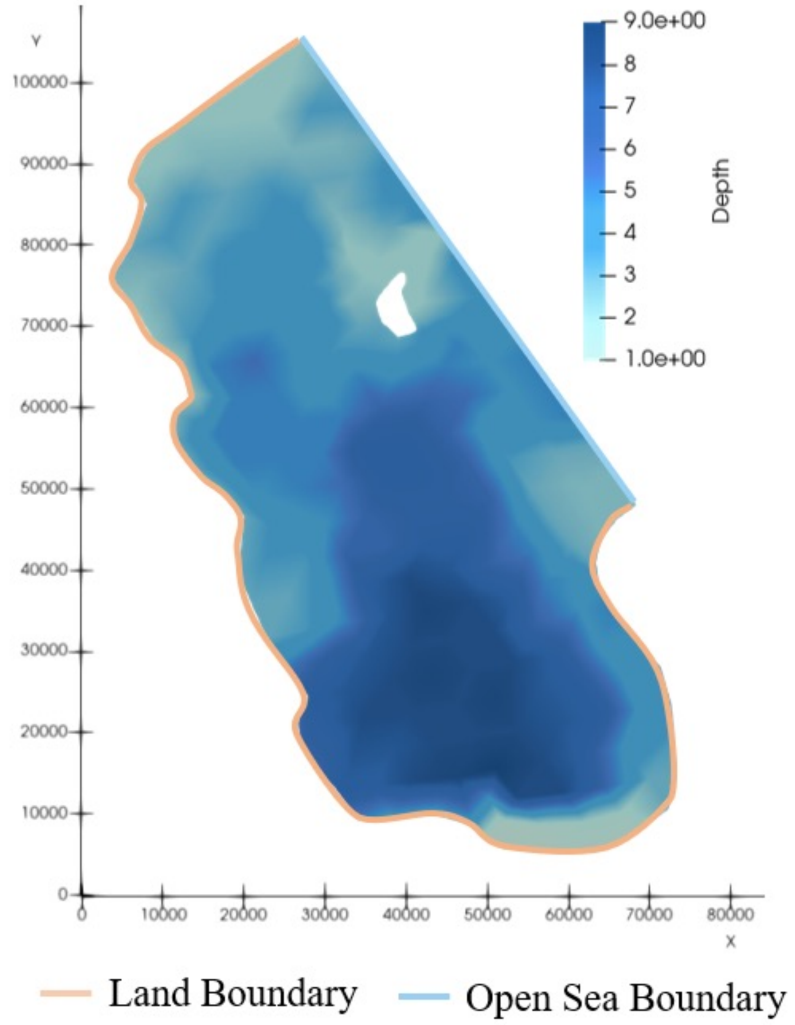
Successful Multi-FPGA Implementations

N-Body Simulation

- Simulation of moving objects
- Applicable to all kinds of scales:
  - from galaxy clusters in space
  - down to atoms
- Idea:
  - calculate forces acting between objects
  - update movement based on forces
  - repeat
- Implemented on 24 FPGAs
  - much better performance scaling than on CPUs

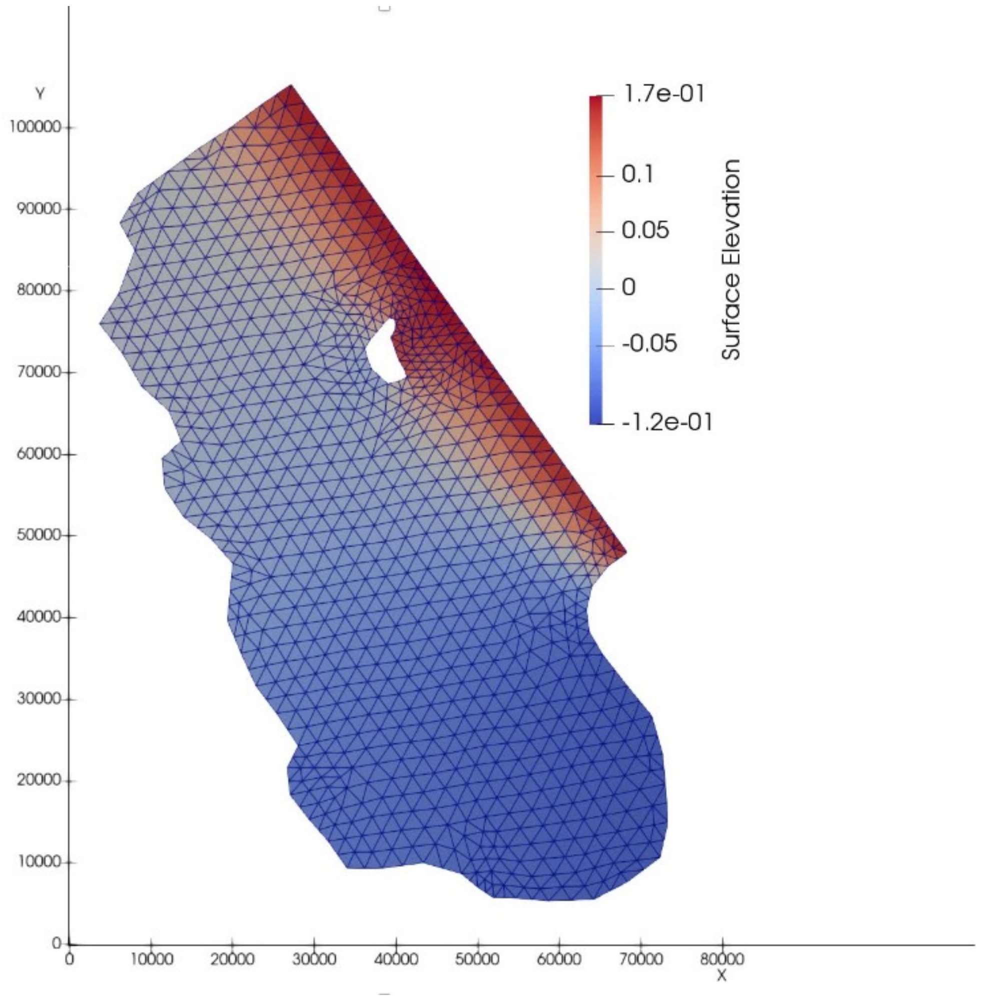


Shallow Water Simulations



- Simulation of water levels / waves near the coast

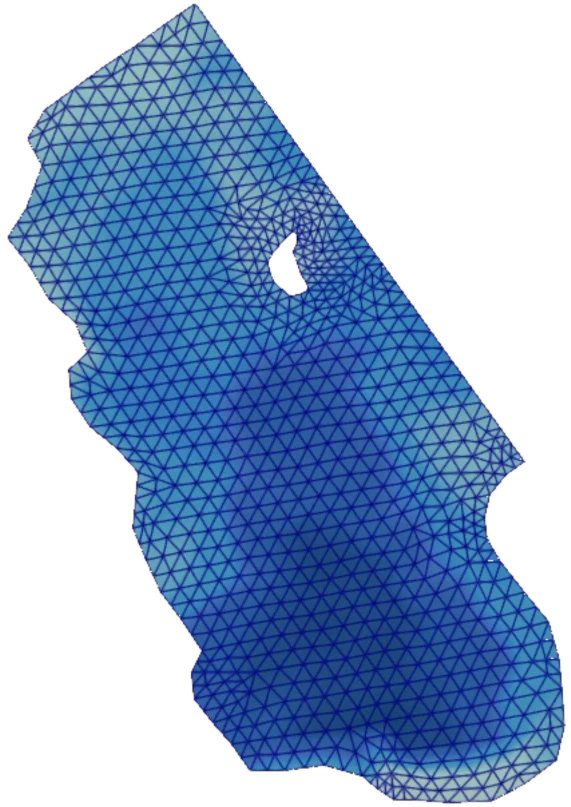
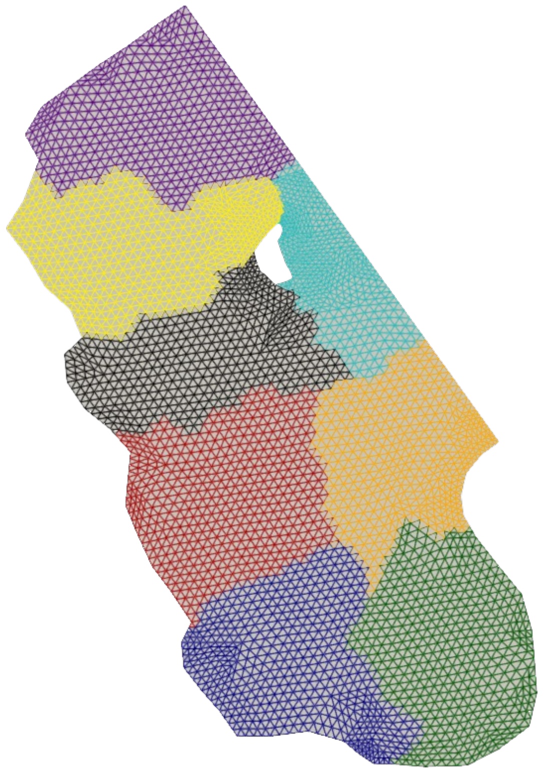
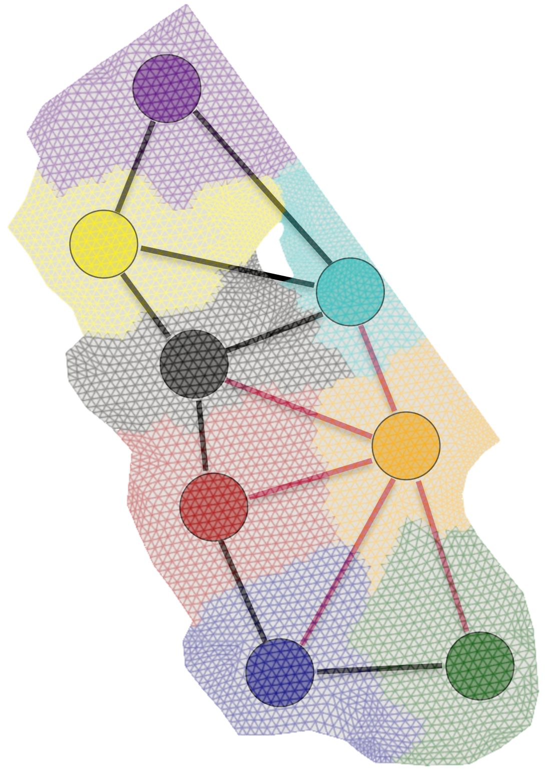
Shallow Water Simulations



- Simulation of water levels / waves near the coast
- Area divided into differently sized elements → “unstructured grid”

Shallow Water Simulations

- Grid partitions distributed among available FPGAs
- Near-perfect scaling with increasing number of FPGAs

Project Group MulFPGA

Goal of the Project Group

- Implement HPC methods or key algorithms on multiple networked FPGAs
- Examples for relevant application domains:
  - Numeric simulations on structured or unstructured grids
  - Dense or sparse linear algebra
  - Parallel graph processing

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What you will do

- Tutorial phase: Get familiar with FPGA programming
- Learn about performance modeling in HPC in general and for FPGA acceleration in particular
- Explore different communication modes for Multi-FPGA applications and characterize them
- Port one or two HPC applications to a Multi-FPGA design, testing different communication variants or using the analytically determined best one

Requirements

- Interest in high-performance computing and accelerator technology

- Familiarity with computer architecture and networking, i.e., terms like
  - Pipelining
  - Parallelism
  - Delay, Bandwidth

- Some programming experience will help
  - FPGAs are programmed using Intel oneAPI (C++ extension), OpenCL, C, C++
  - *No* hardware description languages used (VHDL / Verilog)
  - You don’t have to be an expert in C/C++ but should have the willingness to learn

Requirements

- Interest in high-performance computing and accelerator technology
- Familiarity
  - Pipelinin
  - Parallelis
  - Delay, B
- Some pro
  - FPGAs a
  - *No* hard
  - You don

```
q.submit([&](handler &h) {
  auto acc_A = buffer_A.get_access<access::mode::read>(h);
  auto acc_B = buffer_B.get_access<access::mode::read>(h);
  auto acc_C = buffer_C.get_access<access::mode::write>(h);

  h.single_task<class vector_sum>([=]() {

    for (int i=0; i<10000; i++) {
      acc_C[i] = acc_A[i] + acc_B[i];
    }

  });
}).wait();
```

You will learn about...

- HPC applications and algorithms
- Modern HPC architectures
- Performance estimation / modelling
- Modern development flows for high-performance FPGAs
- Different networking approaches

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Team & Contact

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https://en.cs.uni-paderborn.de/hpc/